THE INTERRELATIONS OF EMOTIONS AS SUGGESTED BY RECENT PHYSIOLOGICAL RESEARCHES*

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I. Introduction

The parts of the organism which are peculiarly activated in affective states are the glands and smooth muscle of the viscera. Although hurried breathing, and trembling, and characteristic bodily postures and facial expressions implicate the skeletal muscles, these muscles, under the will, may be sent into similar patterns without emotional experience, or in the throes of an emotional disturbance they may be set in deceptive patterns of quite opposite meaning—for example, we can smile through our tears. The pouring out of tears, however, and the "cold sweat," the dilation of the pupils, the erection of hairs, the pallor from contracted blood-vessels, the

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rapid heart—all these are changes from the routine of life, in organs not subject to voluntary control, in organs which are only roused thus from their normal even tenor by the rush of a wave of feeling. So characteristic are these disturbances of the viscera in affective states that they have been regarded, in the well known James-Lange theory, as giving rise to the peculiar qualities which differentiate emotional experiences from one another.

II. The General Organization of the Autonomic Nervous System

The glands and the smooth muscle of the viscera are, so far as is now known, never innervated directly from the central nervous system. Always there is interposed between the viscera and cerebrospinal neurones an extra neurone lying wholly outside the central nervous system. These outlying neurones,[1] with cell bodies grouped in ganglia (G's, Fig. 1) or distributed in the viscera themselves (see *e. g.*, heart and stomach, Fig. 1), form the so-called "autonomic system."[2] The neurones connecting the central nervous system with the peripheral ganglia do not pass out in a continuous series all along the cerebrospinal axis, but are separated by the roots of the nerve plexuses of the fore and hind limbs into three divisions. In front of the fore-limb plexus is the cranial division of the autonomic; between the fore-limb and the hind-limb plexuses is the thoracico-lumbar autonomic (or "sympathetic system," in the older terminology); and after the hind-limb plexus is the sacral autonomic. These three parts of the autonomic system have a number of interesting peculiarities.

1. The thoracico-lumbar autonomic is distributed throughout the body—to the eyes, the heart, the lungs, the digestive and genito-urinary tracts, and extensively to the walls of blood vessels and the smooth muscles of hairs.

2. The efferent fibres from the central nervous system may extend through several of the sympathetic ganglia and give off connections to cell bodies of the outlying neurones in each of them (note connections, Fig. 1). Although similar relations exist between afferent sensory fibres and cell bodies in a

[1] Possibly these outlying neurones act as "transformers," modifying the impulses received from the central source, and adapting these impulses to the peculiar tissues—glands and smooth muscle—to which they are distributed.

[2] For most of our knowledge of the organization of this system we are indebted to Langley and his collaborators. See J. N. Langley: *Ergebnisse der Physiologie,* Wiesbaden 1903, ii[2], p. 818, for summary.

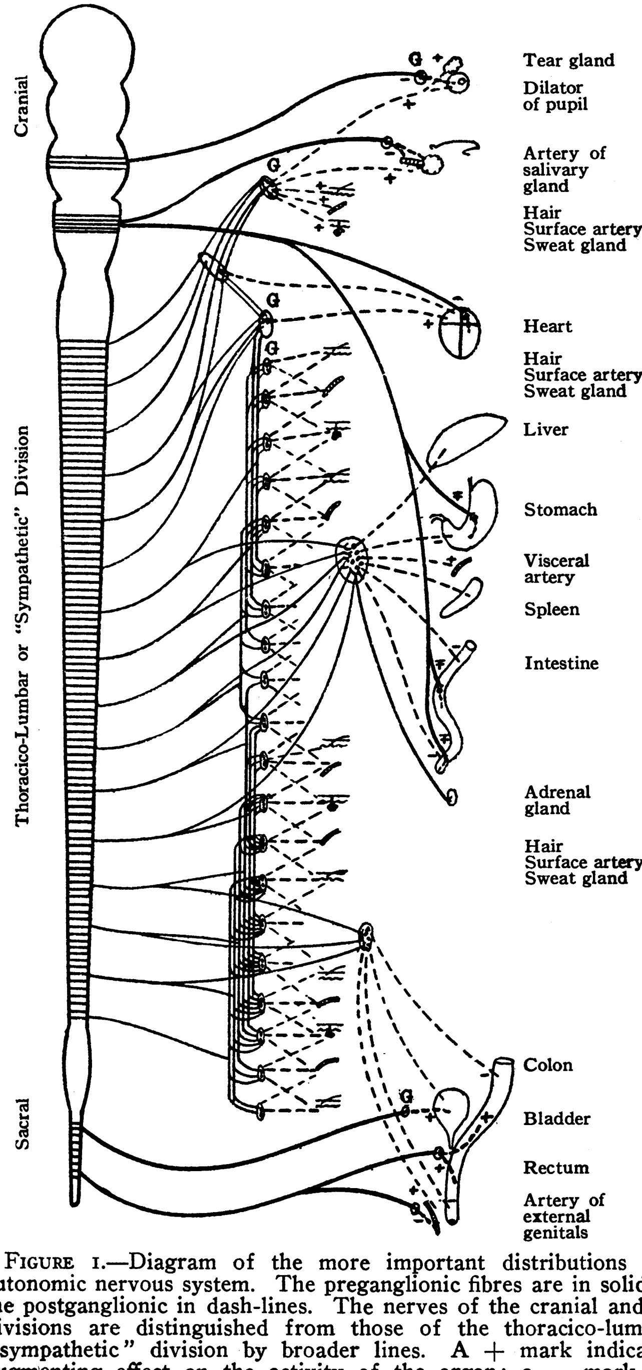

FIGURE 1.—Diagram of the more important distributions of the autonomic nervous system. The preganglionic fibres are in solid lines; the postganglionic in dash-lines. The nerves of the cranial and sacral divisions are distinguished from those of the thoracico-lumbar or "sympathetic" division by broader lines. A + mark indicates an augmenting effect on the activity of the organ; a — mark, a depressive or inhibitory effect.

series of segments in the spinal cord, the operation in the two cases is quite different. In the spinal cord the afferent impulse produces directed and closely limited effects, as, for example, when the left hind limb in a spinal animal flexes in response to a noxious stimulus applied to the left foot, without general involvement of the rest of the body in the response. In the action of the sympathetic, on the other hand, the numerous connections of single fibres with more peripheral neurones, seems to be not at all arranged for specific effects in this or that region. There are, to be sure, variations in the degree of functional involvement of different parts; for example, dilation of the pupil in the cat occurs more readily than erection of the hairs. It may be that specially direct pathways to the eye are present for common use in non-emotional states, and that only slight general disturbance in the nervous system would be necessary to send impulses by these well-worn courses. Thus tears might flow although other parts innervated by the sympathetic might be little disturbed. But we have no means of voluntarily wearing these pathways, and, in general, the neurone relations in the sympathetic seem devised for widespread diffusion of impulses.

3. The cranial and the sacral autonomic divisions differ from the thoracico-lumbar in having only restricted distribution; the cranial to the eyes, the heart, single arteries, the lungs, and the stomach and small intestine; the sacral to single arteries, the distal colon, the bladder and external genitals (see Fig. 1, cranial and sacral distribution).

4. The efferent fibres from the central nervous system to the sacral and cranial divisions of the autonomic have few of the distributed connections typical of the thoracico-lumbar division, but, like nerves to skeletal muscles, innervate separate organs (compare, *e. g.*, cranial and sympathetic supply to heart and stomach, Fig. 1). This singleness and separateness of connection is assured in many instances by the imbedding of the outlying neurones—as in the heart and stomach—in the body of the viscus itself.

5. As indicated in the foregoing lists, many of the viscera are innervated both by the sympathetic and by the cranial or sacral parts of the autonomic. *When the mid-part meets either end-part in any viscus they are antagonists.*[3] Thus the cranial supply to the eye contracts the pupil, the sympathetic dilates it; the cranial slows the heart, the sympathetic accelerates it; the sacral contracts the distal colon, the sympathetic

[3] T. R. Elliott: The Action of Adrenalin. *The Journal of Physiology,* XXXII, 1905, 401-467. See pp. 424, 425.

relaxes it; the sympathetic contracts the urethra, the sacral relaxes it. These effects are indicated in Fig. 1 by + for contraction, acceleration, or increased tone, and by — for inhibition, relaxation, or decreased tone. The vagus nerve has a primary brief inhibitory effect on the stomach and small intestine $\mp$; its chief effect, however, is to produce contraction and increased tone in these organs. Probably these peripheral oppositions have counterparts in the organization of central neurones, just as antagonistic muscles are reciprocally innervated because of central arrangements, for Sherrington has noticed, and I can confirm the observation, that even though the sympathetic is prevented from acting the pupil dilates in a paroxysm of anger—due, no doubt, because the response is rapid, to central inhibition of the cranial supply to the constrictor muscles.

6. The adrenal glands produce a substance (adrenin, epinephrin, or adrenalin) which, in extraordinarily minute amounts, affects the structures innervated by the sympathetic precisely as if they were receiving nervous impulses. Thus adrenalin injected into the blood will cause dilated pupils, erect hairs, rapid heart, constricted bloodvessels, inhibited activities of the alimentary canal, and liberation of sugar from the liver.

7. The adrenal glands are innervated by preganglionic fibres of the autonomic group, and stimulation of these nerve fibres will cause a pouring out of adrenal secretion into the blood stream.[3a]

The foregoing brief sketch of the organization of the autonomic system brings out a number of points that should be of importance as bearing on the nature of the emotions which manifest themselves in the operations of this system. Thus it is highly probable that the sympathetic division, because arranged for diffuse discharge, is likely to be brought into activity as a whole rather than in parts. Also, because antagonisms exist between the middle and either end division of the autonomic, affective states may be classified according to their expression in the middle or an end division and these states would be, like the nerves, antagonistic in character. And finally, since the adrenal glands are innervated by autonomic fibres of the mid-division, and since adrenal secretion stimulates the same activities that are stimulated nervously by this division, it is possible that disturbances in the realm of the sympathetic, although initiated by nervous discharge, are au-

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[3a] T. R. Elliott: The Innervation of the Adrenal Glands. *The Journal of Physiology*, XLVI, 1913, 289 ff.

tomatically augmented and prolonged through chemical action. Some recent researches in which these considerations were kept in mind are now to be reported.

III. The Operation of the Thoracico-Lumbar Autonomic Division in Pain, Fear and Rage

When a dog barks at a cat in confinement, the cat may strive to escape or crouch in a farther part of the cage, or it may rush forward in attack. The changes of smooth-muscle functions in the animal, either in crouching fear or in attacking rage, are much the same. The pupils are large, the motions of the stomach and intestines are inhibited, and the hair is erect on the back and tail—from one end to the other, the animal shows the effects of sympathetic innervation.[4] Do the adrenal glands share in this general excitation of the mid-division of the autonomic at times of great emotional stress?

This question was taken up by de la Paz and myself about three years ago.[5] We found that when a cat is frightened or enraged by a barking dog, blood near the opening of the adrenal veins gave definite evidence of the presence of adrenalin (tested by relaxation of the rhythmically-contracting intestinal strip), whereas blood from the same region previous to the excitement was ineffective. Later Hoskins and I found that strong stimulation of the sciatic nerve in an anaesthetized animal—such stimulation as would cause severe pain if the animal were not anaesthetized—resulted in greater activity of the adrenal medulla, as indicated by the increased amount of adrenalin in the blood.[6]

These observations on the effects of fear, rage and pain have been supported by Elliott's study of the adrenalin content of the adrenal glands as affected by experimental procedures.[7] He found that " fright," induced in cats by morphia or by β-tetrahydronaphthylamine, exhausts the glands, and that excitation of afferent nerves, such as the great sciatic, also causes adrenalin to disappear. These results are what could be reasonably expected, for major emotions, as fear and rage, and

[4] W. B. Cannon: *The Mechanical Factors of Digestion,* London and New York, 1911, pp. 227. See p. 217.

[5] W. B. Cannon and D. de la Paz: Emotional Stimulation of Adrenal Secretion, *American Journal of Physiology,* XXVIII, 1911, 64-70, see p. 64.

[6] W. B. Cannon and R. G. Hoskins: The Effects of Asphyxia, Hyperpnoea, and Sensory Stimulation on Adrenal Secretion. *American Journal of Physiology,* XXIX, 1911, 274-279, see p. 278.

[7] T. R. Elliott: The Control of the Suprarenal Glands by the Splanchnic Nerves. *Journal of Physiology,* XLIV, 1912, p. 409.

such sensory stimulation as in a conscious animal would be painful, are known to be accompanied by nerve impulses passing out via sympathetic fibres—impulses causing dilation of the pupils, inhibition of gastric peristalsis and secretion, and contraction of arterioles. And, as previously stated, the adrenal glands have been proved to manifest increased secretory activity when affected by nerve impulses coming via these same pathways.

Artificial stimulation of splanchnic nerves not only liberates adrenalin but also releases sugar from the liver.[8] Sugar is thus so greatly increased in the blood that it appears in the urine (glycosuria). If, however, the adrenals are removed from the body, splanchnic stimulation will not evoke glycosuria. The participation of the adrenal medulla, therefore, seems to be essential for the mobilization of sugar in the blood, when that is accomplished by nerve impulses.

Since adrenal secretion is increased in major emotional states and on stimulation of nerves for pain,—and since hyperglycaemia is the normal accompaniment of such experimental nervous stimulations as evoke an increased adrenal secretion, it might reasonably be expected that fear, rage and pain would give rise to hyperglycaemia.

That experimental procedures attended by pain result in the appearance of sugar in the urine was demonstrated many years ago by Böhm and Hoffman.[9] Their observations on cats have been corroborated on rabbits;[10] and recently it has been shown that an operation involving some pain increases blood sugar in dogs.[11]

That pure emotional excitement—fear or rage—will have the same effect, was proved when Shohl, Wright and I obtained glycosuria in cats by fastening them to a comfortable holder or by placing them in small cages and permitting a dog to bark at them. Whether glycosuria appeared promptly or not depended on the animal's emotional reaction to its experience. Neither pain nor being bound, therefore, was a factor in the

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[8] J. J. R. Macleod: *Diabetes: its Pathological Physiology,* London, 1913, see pp. 61-62.

[9] R. Böhm and F. A. Hoffman: Beiträge zur Kenntniss des Kohlenhydratstoffwechsels. *Archiv für experimentelle Pathologie und Pharmakologie,* VIII, 1878, 271-308, see p. 295.

[10] C. Eckhard: Zur Deutung der Entstehung der vom vierten Ventrikel aus erzeugbaren Hydrusien. *Zeitschrift für Biologie,* XLIV, 1903, 407-440, see p. 408.

[11] A. Loewy and S. Rosenberg: Ueber die normale Höhe des Blutzuckergehalts bei Kaninchen und Hunden. *Biochemische Zeitschrift,* LVI, 1913, 114-116, see p. 114.

result—the essential element was the fright or rage of the animal.[12] Our conclusion has been confirmed by one of my former students, Dr. W. G. Smillie, who found that four of nine medical students (all normally aglycosuric) had glycosuria after a very exacting examination, whereas only one of the nine had glycosuria after an easier examination.[13] Also Rolly and Oppermann,[14] Jacobsen,[15] and Hirsch and Reinbach[16] have recently reported that the mere handling of a rabbit preparatory to operating on it will increase the blood sugar (in some cases from 0.10 to 0.23 and 0.27 per cent) and may result in glycosuria. Indeed, the readiness with which this response occurs has been pointed out as a source of error in estimates of the "normal" sugar content of the blood.

Fear, rage and pain, therefore, are accompanied by an increased discharge of adrenalin into the blood, and by a freeing of stored glycogen from the liver for circulation through the body as dextrose. What explanation can be offered for this remarkable outpouring from the adrenal medulla and the concomitant glycogenolysis that floods the body with sugar?

1. The Reflex Nature of Bodily Responses to Pain and the Major Emotions

The most significant feature of these bodily reactions to pain and to emotion-provoking objects is that they are of the nature of reflexes,—they are not willed movements, indeed they are often distressingly beyond the control of the will. The pattern of the reaction, in these as in other reflexes, is deeply inwrought in the workings of the nervous system, and

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[12] W. B. Cannon, A. T. Shohl and W. S. Wright: Emotional Glycosuria. *American Journal of Physiology,* XXIX, 1911, 280-287, see p. 283.

[13] The tests were made on the first urine passed after the examination. Mr. C. H. Fiske and I have found sugar in the urine in 12 of 25 members of the Harvard University football squad, immediately after the final and most exciting contest of the season. Five of the positive cases were substitutes who were not called upon to enter the game.

[14] F. Rolly and F. Oppermann: Das Verhalten des Blutzuckers bei Gesunden und Kranken. *Biochemische Zeitschrift,* XLIX, 1913, 278-292, see p. 201.

[15] A. T. B. Jacobsen: Untersuchungen über den Einfluss des Chloralhydrats auf experimentelle Hyperglykaemieformen. *Ibid,* LI, 1913, 442-462, see p. 449.

[16] E. Hirsch and H. Reinbach: Die Fesselungshyperglykämie und Fesselungsglycosurie des Kaninchens. *Zeitschrift für physiologische Chemie,* LXXXVII, 1913, 122-141, see p. 137.

when the appropriate occasion arises, typical organic responses are evoked through inherent automatisms.

It has long been recognized that the most characteristic feature of reflexes is their "purposive" nature, or their utility either in preserving the welfare of the organism or in safeguarding it against injury. The reflexes of sucking, swallowing, vomiting and coughing, for instance, need only to be mentioned to indicate the variety of ways in which reflexes favor the continuance of existence. When, therefore, these automatic responses accompanying pain and fear and rage—the increased discharge of adrenalin and sugar—are under consideration, it is reasonable to inquire first as to their utility.

Numerous ingenious suggestions have been offered to account for the more obvious changes accompanying emotional states—as, for example, the bristling of the hair and the uncovering of the teeth in an access of rage. The most widely applicable explanation[17] proposed for these spontaneous reactions is that during the long course of racial experience they have been developed for quick service in the struggle for existence. McDougall[18] has suggested that an association has become established between peculiar emotions and these ingrained native reactions; thus the emotion of fear is associated with the instinct for flight, and the emotion of anger or rage with the instinct for fighting or attack. Earlier James had pointed out that "fear has bodily expressions of an extremely energetic kind, and stands, beside lust and anger, as one of the three most exciting emotions of which our nature is susceptible."[19]

Because the adrenalinaemia and the hyperglycaemia following painful or strong emotional experiences are reflex in character, and because reflexes as a rule are useful responses, we may reasonably enquire whether under these circumstances the increase of adrenalin and sugar in the blood is useful. What then is the possible value of these reactions?

In order that these reactions may be useful they must be *prompt*. Such is the case. Some recent observations have shown that the latent period of adrenal secretion, when the splanchnic nerve is stimulated below the diaphragm, is not longer than 16 seconds; and Macleod states that within a few minutes after splanchnic stimulation the sugar in the blood

[17] Chas. Darwin: *Expression of Emotions in Man and Animals*, New York, 1905, pp. 374, see pp. 101 and 117.

[18] William McDougall: *Introduction to Social Psychology*, London, 1908, pp. 355, see pp. 49 and 59.

[19] William James: *Principles of Psychology*, New York, 1905, 2 vols., see II, p. 415.

rises between 10 and 30 per cent.[20] The two secretions are, therefore, almost instantly ready for service.

Conceivably the two secretions might act in conjunction or each might function alone. Thus adrenalin might serve in co-operation with nervous excitement to produce increase of blood sugar, or it might have that function and other functions quite apart from that. Before these possibilities are considered, however, the value of the increased blood sugar itself will be discussed.

2. *The Utility of Increased Blood-Sugar*

In the paper on emotional glycosuria previously mentioned,[21] a clue was taken from McDougall's suggestion of a relation between "flight instinct" and "fear emotion," and "pugnacity instinct" and "anger emotion." And the point was made that, since the fear emotion, and the anger emotion are, in wild life, likely to be followed by activities (running or fighting) which require contraction of great muscular masses in supreme and prolonged struggle, a mobilization of sugar in the blood might be of signal service to the laboring muscles. Pain—and fighting is almost certain to involve pain—would, if possible, call forth even greater muscular effort. "In the agony of pain almost every muscle of the body is brought into strong action," Darwin wrote, for "great pain urges all animals, and has urged them during endless generations, to make the most violent and diversified efforts to escape from the cause of suffering."[22]

That muscular work is performed by energy supplied in carbonaceous material is shown by the great increase of carbon-dioxide output in severe muscular work, which may exceed twenty times the output during rest. Furthermore, the storage of glycogen in muscle, and the disappearance of this glycogen deposit from excised muscle stimulated to activity, or its reduction after excessive contractions produced by

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[20] J. J. R. Macleod: *Loc. cit.*, see p. 80.

[21] W. B. Cannon, A. T. Shohl and W. S. Wright: *Loc. cit.*, see p. 286.

[22] Chas. Darwin: *Loc. cit.*, p. 72. It is recognized that both pain and the major emotions may have at times depressive rather than stimulating effects. Though severe pain may soon induce extreme prostration, the whip and spur illustrate its primary exciting action. And though fear may become the most depressing of all emotions, it acts at first as a powerful stimulus. "A man or animal driven through terror to desperation is endowed with wonderful strength, and is notoriously dangerous in the highest degree." (Darwin: *Loc. cit.*, p. 81).

strychnine, and the lessened ability of muscles to work if their glycogen store has been reduced, and the simple chemical relation between sugar and the lactic acid which appears when muscles are repeatedly made to contract, are all indications that carbohydrate (sugar and glycogen) is the elective source of energy for contraction. This conclusion is supported in recent careful studies by Benedict and Cathcart,[23] who have shown that a small but distinct increase in the respiratory quotient occurs during muscular work, and that a decrease in the quotient follows, thus pointing to a larger proportion of carbohydrate burned during muscular work than before or after—*i. e.*, a call on the carbohydrate deposits of the body.

Furthermore, there is considerable evidence that the increasing of blood sugar directly increases muscular efficiency. Thus Locke proved that if oxygenated salt solution is perfused through the rabbit heart, the beats begin to weaken after one or two hours; but if now 0.1 per cent dextrose is added to the perfusing fluid the beats at once become markedly stronger and may continue with very slow lessening of strength as long as seven hours.[24] And Schumberg noted that when he performed a large amount of general bodily work (thus using up blood sugar) and then tested flexion of the middle finger in an ergograph, the ability of the muscle was greater if he drank a sugar solution than if he drank an equally sweet solution of "dulcin."[25] He did not know during the experiment which solution he was drinking. These observations have been confirmed by Prantner and Stowasser, and by Frentzel.[26] In experiments on cats Lee and Harrold found that when sugar is removed from the animal by means of phlorhizin the *tibialis anticus* muscle is quickly fatigued; but if, after the phlorhizin treatment, the animal is given an abundance of sugar and then submitted to the test, the muscle shows a much larger capacity for work.[27] All this evidence is, of course,

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[23] F. G. Benedict and E. R. Cathcart: *Muscular Work, a metabolic study*, Washington, 1913, pp. vi + 176, see pp. 85-87.

[24] F. S. Locke: Die Wirkung der Metalle des Blutplasma auf das isolierte Säugethierherz. *Centralblatt für Physiologie*, XIV, 1900, 670-672, see p. 671.

[25] Dr. Schumberg: Einfluss des Zuckergenuses auf die Leistungsfahigkeit der Musculatur. *Archiv für Physiologie, Jahrgang*, 1896, 537-538, see p. 537.

[26] Johannes Frentzel: Ergographische Versuche über die Nährstoffe als Kraftspender für ermüdete Muskeln. *Archiv für Physiologie, Jahrgang*, 1899, Supplement Band, 141-159, see p. 145.

[27] Frederic Lee and C. C. Harrold: The Action of Phlorhizin on Muscle, Proceedings of the Amer. Physiological Society, 5th Special Meeting. *American Journal of Physiology*, IV, 1900, ix-x.

favorable to the view that circulating sugar may be quickly utilized by contracting muscles.

Experimental studies have shown, then, that muscles work preferably by utilizing the energy stored in sugar, that great muscular labor is capable of considerably reducing the quantity of stored glycogen and of circulating sugar, and that under circumstances of a lessened sugar content the increase of blood sugar considerably augments the ability of muscles to continue contracting. The conclusion seems justified, therefore, that the increase of blood sugar attendant on the major emotions and pain, is of direct benefit to the organism in the strenuous muscular efforts involved in flight or conflict or struggle to be free.

3. The Utility of Increased Adrenalin in the Blood

In early work on the effects of removal of the adrenal bodies muscular weakness was not infrequently noted. In 1892, Albanese showed that muscles stimulated after adrenalectomy were much more exhausted than when stimulated the same length of time in the same animal before the removal.[28] Similarly Boinet reported that rats recently deprived of their adrenal glands were much more quickly exhausted in a revolving cage than were normal animals.[29] A beneficial effect of adrenal extract on fatigued muscle, even when applied to the solution in which the isolated muscle is contracting, was claimed by Dessy and Grandis,[30] who studied the phenomenon in the salamander.

It seemed possible, because of the early evidence that adrenalectomy has a debilitating effect on muscular power, and that injection of adrenal extract has an invigorating effect, that increased adrenal secretion, as a reflex result of pain or the major emotions, might not only be useful in helping to mobilize sugar, but also might act in itself as a dynamogenic factor

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[28] M. Albanese: La fatigue chez les animaux privés des capsules surrénales. *Archives italiennes de biologie,* XVII, 1892, 239-247, see p. 243.

[29] E. Boinet: Résistance à la fatigue de 11 rats décapsulés, depuis cinq et six mois. *Comptes rendus, la Societe de Biologie,* Tome II, 10. Serie, XLVII de la collection, 1895, 162-167. Nouvelles recherches sur la résistance à la fatigue de rats décapsulés depuis longtemps. *Ibid.,* 325-326.

[30] S. Dessy and V. Grandis: Contribution à l'étude de la fatigue. Action de l'adrenaline sur la fonction du muscle. *Archives italiennes de biologie* XLI, 1904, 225-233, see p. 231.

in the performance of muscular work. On the basis of this possibility Nice and I[31] tested the effect of stimulating the left splanchnic nerve (thus causing adrenal secretion), or injecting adrenalin, on the contraction of the fatigued *tibialis anticus*. We found that when arterial pressure was of normal height, and was prevented from rising in the legs while the splanchnic nerve was being stimulated, there was a distinct rise in the height of contraction of the fatigued muscle. We drew the inference that adrenalin set free in the blood may operate favorably to the organism by preparing fatigued muscles for better response to the nervous discharges sent forth in great excitement.

This inference has been further tested by one of my students, Mr. C. M. Gruber,[32] who has examined the effects of minute amounts of adrenalin (0.1 or 0.5 c. c. of 1:100,000), and also of splanchnic stimulation, on the threshold stimulus of fatigued neuromuscular and muscular apparatus. Fatigue raises the threshold not uncommonly 100 or 200 per cent and in some instances as much as 600 per cent. Rest will restore the normal threshold in periods varying from 15 to 120 minutes, according to the length of previous stimulation. If a small dose of adrenalin is given, however, the normal threshold may be restored in three to five minutes.

From the foregoing evidence the conclusion is warranted that adrenalin, when freely liberated in the blood, not only aids in bringing out sugar from the liver's store of glycogen, but also has a remarkable influence in quickly restoring to fatigued muscles, which have lost their original irritability, the same readiness for response which they had when fresh. Thus the adrenalin set free in pain and in fear and rage would put the muscles of the body unqualifiedly at the disposal of the nervous system; the difficulty which nerve impulses might have in calling the muscles into full activity would be practically abolished; and this provision, along with the abundance of energy-supplying sugar newly flushed into the blood, would give to the animal in which these mechanisms are most efficient the best possible conditions for putting forth supreme muscular efforts.

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[31] W. B. Cannon and L. B. Nice: The Effect of Adrenal Secretion on Muscular Fatigue. *American Journal of Physiology,* XXXII, 1913, 44-60, see p. 54.

[32] C. M. Gruber: Studies in Fatigue III. The Fatigue Threshold as affected by Adrenalin and by Increased Arterial Pressure. *American Journal of Physiology,* XXXIII, 1914, 333-355, see p. 354.

4. *The Utility of the Vascular Changes Produced by Adrenalin*

Quite in harmony with the foregoing argument that sugar and adrenalin, which are poured into the blood during emotional excitement, render the organism more efficient in the physical struggle for existence, are the vascular changes wrought by increased adrenalin, probably in coöperation with sympathetic innervations. Through oncometric studies, Oliver and Schäfer[33] proved that the viscera of the splanchnic area —as the spleen, the kidneys, and the intestines—suffer a considerable diminution of volume when adrenalin is administered, whereas the limbs into which the blood is forced from the splanchnic region, actually increase in size. In other words, at times of stress, blood may be driven out of vegetative organs of the interior, which serve the routine needs of the body, into the skeletal muscles, which have to meet by extra action the urgent demands of conflict.

But there are exceptions to the statement that by adrenalin the viscera are emptied of their blood. It is well known that adrenalin has a vasodilator, not a vasoconstrictor, effect on the arteries of the heart; it is well known also that adrenalin affects the intracranial and the pulmonary vessels only slightly, if at all.[34]

Thus the absolutely essential organs—the "tripod of life" (heart, lungs, and brain) as well as the skeletal muscles —are, in times of excitement, when the adrenal glands discharge, abundantly supplied with blood taken from organs of less importance in critical moments.

The cessation of activities of the alimentary canal (thus freeing the energy supply for other parts); the shifting of the blood from the less insistent abdominal viscera to the organs immediately vital, such as the lungs, the heart, the central nervous system, and, at critical moments, the skeletal muscles as well; the increased cardiac vigor; the quick abolition of the effects of muscular fatigue; the mobilizing of energy-giving sugar in the circulation—these are the changes which occur when in fear or rage or pain the adrenal glands are made to pour forth an excessive secretion. These changes doubtless represent to some degree the reservoirs of power

[33] George Oliver and E. A. Schäfer: The Physiological Effects of Extracts of the Suprarenal Capsules. *Journal of Physiology,* XVIII, 1895, 230-276, see p. 240.

[34] A. Biedl: *Innere Sekretion,* Second Edition, Leipzig, 1913, 2 vols., see I, pp. 434, 435.

which, as James suggested,[34a] exist in our bodies and are ready to be tapped in times of need. The changes are, each one of them, *directly serviceable in making the organism more efficient in the struggle which fear or rage or pain may involve;* for fear and rage are aspects of organic preparations for action, and pain attends conditions which naturally evoke supreme exertion. And the organism which with the aid of increased adrenal secretion can best muster its energies, best call forth sugar to supply the laboring muscles, best lessen fatigue, and best send blood to the parts essential in the run or the fight for life, is most likely to survive.

IV. The Operation of the Cranial Autonomic Division in the Pleasures of Appetite

The well-known researches of Pawlow[35] have made clear the importance of appetite and the relish of food in causing secretion of the digestive glands. The mere showing of desirable food to a dog causes the saliva and the gastric juice to be poured forth in a true psychic secretion. And if the dog has an opening in the oesophagus so that food does not go to the stomach, the repeated chewing and swallowing of appetizing morsels (" sham feeding ") is accompanied by constant and prolonged production of gastric juice. All these glands—both the salivary group and those of the gastric wall—are innervated by cranial autonomic fibres (See Fig. 1). Section of these fibres abolishes the psychic secretion.

These observations on dogs have been almost completely confirmed by studies of human beings having oesophageal obstruction and an opening through the body wall into the stomach. Hornborg,[36] Bogen[37] and others have reported such cases in detail. Hornborg found that when the boy whom he examined chewed agreeable food a more or less active secretion of gastric juice was started, whereas the chewing of indifferent material was without influence.

In studying the mechanical aspect of digestion also, I was led to infer that there is probably a "psychic tone" or "psychic

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[34a] William James: *Energies of Man*, New York, 1910.

[35] J. P. Pawlow: *The Work of the Digestive Glands*. London, 1902.

[36] A. F. Hornborg: Beiträge zur Kenntniss der Absonderungsbedingungen des Magensaftes beim Menschen. *Skandanavisches Archiv für Physiologie*, XV, 1904, 209-256, see p. 248.

[37] H. Bogen: Experimentelle Untersuchungen über psychische und associative Magensaftsecretion beim Menschen. *Archiv für die gesammte Physiologie*, CXVII, 1907, 150-160, see p. 156.

contraction" of the muscles as a result of taking food. For if the vagus autonomic fibres are severed immediately before food is taken into the stomach, the usual contractions of the gastric wall do not occur; but if these fibres are severed after food has been eaten with relish the contractions which have started continue without cessation. Thus, just as the secretions are started by pleasurable taste and smell, the conditions for peristalsis may also have a basis in mild affective states.[38]

Aside from positive effects on the muscles of the alimentary tract and its accessory glands, cranial autonomic fibres cause contraction of the pupil of the eye, and slowing of the heart rate.

A glance at these various functions of the cranial division shows at once that they serve for bodily conservation—for the shielding of the retina from excessive light, for the resting and upbuilding of the heart, and for the taking in and storing of energy-bearing material through proper digestion and absorption.

V. The Operation of the Sacral Autonomic in Reflexes for Emptying

Sacral autonomic fibres cause contraction of the rectum and distal colon and also contraction of the bladder. In both instances the effects result from stretching of the tonically contracted viscera by their accumulating contents. No affective states precede the normal actions of the sacral division and even those which accompany or follow them are only mildly positive; a feeling of relief rather than of elation usually attends the completion of the act—there is, however, testimony to the contrary.

The sacral autonomic fibres also include the nervi erigentes which bring about engorgement of erectile tissue in the external genitals. According to Langley and Anderson[39] the sacral nerves have no effect on the *internal* generative organs. The vasa deferentia and the seminal vesicles whose rhythmic contractions mark the acme of sexual excitement in the male, and the uterus whose contractions in the female are probably analogous, are supplied only by lumbar branches—part of the

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[38] W. B. Cannon: *The Mechanical Factors of Digestion.* See p. 200.

[39] J. N. Langley and H. K. Anderson: The Innervation of the Pelvic and Adjoining Viscera, Parts II-V. *Journal of Physiology,* XIX, 1895, 71-139, see pp. 85, 122.

sympathetic division. These branches also act in opposition to the nervi erigentes and cause constriction of the blood vessels of the external genitals. The sexual organism involves a high degree of emotional excitement; but it can be rightly considered as essentially a reflex mechanism; and, again in this instance, distention of tubules, vesicles and blood vessels can be found at the beginning of the incident, and relief from this distension at the end.

Although distention is the commonest occasion for bringing the sacral division into activity it is not the only occasion. Great emotion, such as is accompanied by nervous discharges via the thoracico-lumbar division may also be accompanied by discharges via the sacral fibres. The involuntary voiding of the bladder and lower gut at times of violent mental stress is well known. Veterans of our Civil War testify that just before the beginning of a battle many of the men had to retire temporarily from the firing line. And the power of sights and smells and libidinous thoughts to disturb the regions controlled by the nervi erigentes proves that this part of the autonomic system also has its peculiar affective states. The fact that one part of the sacral division, *e. g.*, the distribution to the bladder, may be in abeyance while another part, *e. g.*, the distribution to the rectum, is active, illustrates in this division the directive rather than the diffuse discharge of impulses which has been previously described.

Like the cranial division, the sacral is engaged in internal service to the body, in the performance of acts leading immediately to greater comfort.

VI. The Antagonism of Affective States Expressed in Opposed Divisions of the Autonomic System

Affective states gain expression through nervous discharges along autonomic pathways. When the nerve fibres of the mid-division of the autonomic system, however, meet in any organ the nerve fibres of either of the end divisions, the two sets are antagonists. As stated above, there is evidence that central arrangements exist for reciprocal innervation of these antagonistic divisions, just as there is reciprocal innervation of antagonistic skeletal muscles. The characteristic affective states manifested in these different divisions have been described. Undoubtedly these states have correspondents in the central neurones. The question now arises, are the states which appear in opposed divisions also in opposition?

1. Antagonism between the Thoracico-lumbar and Cranial Divisions

The cranial autonomic, as already shown, is concerned with the quiet service of building up reserves, and fortifying the body against times of stress. Accompanying these functions are the relatively mild pleasures of the sight and taste and smell of food. The possibility of existence of these gentle delights of eating and drinking and also of their physiological consequences is instantly swept away by affective states which activate the sympathetic division.

The stoppage of salivary flow and the consequent drying of the mouth, in fear and great anxiety, have been made familiar in the ordeal of rice. Failure of gastric secretion also has been demonstrated. Thus Hornborg was unable to confirm in his patient Pawlow's observation that mere showing of food to a hungry subject causes a flow of gastric juice. The difference in results was due to difference in the reaction of the subjects to the situation. When food was shown, but withheld, Pawlow's hungry dogs were all eagerness to secure it, and the juice at once began to flow. Hornborg's little boy, on the contrary, became vexed when he could not get the food, and began to cry; then no secretion appeared. Bogen also reported that his patient, aged about four years, sometimes fell into such a passion after vain hoping for food that the giving of food after calming the child, was not followed by any secretion of gastric juice.

The observations of Bickel and Sasaki[40] confirm and define more precisely the inhibitory effects of violent emotion on gastric secretion. In their control observations sham feeding was attended by a copious flow of gastric juice, a "psychic secretion," resulting from the pleasurable taste of the food. In a typical instance the sham feeding lasted five minutes, and the secretion continued for twenty minutes, during which time 66.7 c. c. of pure gastric juice was produced.

On another day a cat was brought into the presence of the dog, whereupon the dog flew into a great fury. The cat was soon removed, and the dog pacified. Now the dog was again given the sham feeling for five minutes. In spite of the fact that the animal was hungry and ate eagerly, there was no secretion worthy of mention. During a period of twenty minutes, corresponding to the previous observation, only 9 c. c.

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[40] A. Bickel and F. Sasaki: Experimentelle Untersuchungen über den Einfluss von Affekten auf die Magensaftsekretion. *Deutsche medizinische Wochenschrift,* XXXI, 1905, 1829-1831, see p. 1829.

of acid fluid was produced, and this was rich in mucus. It is evident that in the dog, as in the boy observed by Bogen, strong emotions can so profoundly disarrange the mechanisms of secretion that the natural nervous excitation accompanying the taking of food cannot cause the normal flow.

On another occasion Bickel and Sasaki started gastric secretion in the dog by sham feeding, and when the flow of gastric juice had reached a certain height, the dog was infuriated for five minutes by the presence of the cat. During the next fifteen minutes there appeared only a few drops of a very mucous secretion. Evidently in this instance a physiological process, started as an accompaniment of a psychic state quietly pleasurable in character, was almost entirely stopped by another physiological process accompanied by a psychic state violent in character.

Not only are the secretory activities of the stomach unfavorably affected by strong emotions; but, as already indicated, the movements of the stomach and, indeed, the movements of almost the entire alimentary canal are wholly stopped during excitement. In my earliest observations on the movements of the stomach I[41] had difficulty, because in some animals the peristalsis was perfectly evident and in others there was no sign of activity. Several weeks passed before I discovered that this difference in response to the presence of food in the stomach was associated with a difference of sex: the male cats were restive and excited on being fastened to the holder, and under these circumstances gastric peristalsis was absent; the female cats, especially if elderly, submitted with calmness to the restraint, and in them peristaltic waves took their normal course. Once a female with kittens turned from her state of quiet contentment to one of apparent restless anxiety. The movements of the stomach immediately stopped, and only started again after the animal had been petted and had begun to purr. I later found that by covering the cat's mouth and nose with the fingers until a slight distress of breathing occurred, the stomach movements could be stopped at will. Thus, in the cat, any sign of rage, such as Bickel and Sasaki's dog manifested, or distress, or mere anxiety, was accompanied by a total cessation of the movements of the stomach.

Just as the secretory activity of the stomach is affected in similar fashion in man and in lower animals, so likewise gastric and intestinal peristalsis are stopped in man as they are

[41] W. B. Cannon: The Movements of the Stomach Studied by Means of the Röntgen Rays. *American Journal of Physiology,* I, 1898, 359-382, see p. 380.

stopped in the lower animals, during worry and anxiety and the major affective states. Indeed the feeling of heaviness in the epigastrium commonly complained of by nervous persons may be due to inactivity of the canal and to stagnation of food. That such stagnation occurs in human beings has been proved by examination of the gastric contents after excitement, when the meal eaten twelve hours or more previously has been found still present.

All these disturbances of digestion seem mere interruptions of the "normal" course of events unless the part they may play in adaptive reactions is considered. In discussing the operations of the sympathetic division I pointed out that all the bodily changes which occur in the intense emotional states —such as fear and fury—occur as results of sympathetic discharges, and are in the highest degree serviceable to the organism in the struggle for existence likely to be precipitated when these emotions are aroused. From this point of view these perturbations which so readily seize and dominate the organs commonly controlled by the cranial autonomic are bodily reactions which may be of the utmost importance to life at times of critical emergency. Thus are the body's reserves—the stored adrenalin, and the accumulated sugar—called forth for instant service; thus is the blood shifted to nerves and muscles that may have to bear the brunt of struggle; thus is the heart set rapidly beating to speed the circulation; and thus, also, are the activities of the digestive organs for the time abolished. Just as in war between states the arts and industries which have brought wealth and contentment must suffer serious neglect or be wholly set aside both by the attacker and the attacked, and all the supplies and energies developed in the period of peace must be devoted to the coming conflict; so, likewise, the functions which in quiet times establish and support the bodily reserves are, in times of stress, instantly checked or abolished, and these reserves lavishly drawn upon to increase power in the attack and in the defence or flight.

It is, therefore, the natural antagonism between these two processes in the body—between conservation and liberation, between anabolism and catabolism—and the correlated antagonism of central innervations (see p. 259), that underlie the antipathy between the affective states which normally accompany the processes. The desire for food, the relish of eating it, all the pleasures of the table, are naught in the presence of anger or great anxiety. And of the two sorts of affective states those which manifest themselves in the dominant division of the autonomic, hold the field also in consciousness.

2. *Antagonism between the Thoracico-lumbar and Sacral Divisions*

The nervi erigentes are the part of the sacral autonomic in which the peculiar excitements of sex are expressed. As previously stated, these nerves are opposed by branches from the thoracico-lumbar division—the division which is operated characteristically in the major emotions.

The opposition in normal individuals between the affective states which appear in these two antagonistic divisions is most striking. Even in animals as low in the scale as birds copulation is not performed " until every condition of circumstance and sentiment is fulfilled, until time, place and partner all are fit."[42] And among men the effect of fear or momentary anxiety or any intense emotional interest in causing inhibition of the act can be supported by cases in the experience of any physician with extensive practice.[42a]

As the acme of excitement is approaching it is probable that the thoracico-lumbar division is also called into activity; indeed, the completion of the process—the contractions of the seminal vesicles and the prostate, and the subsidence of engorged tissues, all innervated by sympathetic filaments (see pp. 271-2)—may be due to the overwhelming of sacral by thoracico-lumbar nervous discharges. As soon as this stage is reached the original feeling likewise has been dissipated.

The other parts of the *sacral* division which supply the bladder and rectum are so nearly free from any affective tone in their normal reflex functioning that it is unnecessary to consider them further with reference to emotional antagonisms. Mild affective states, such as worry and anxiety, can, to be sure, check the activity of the colon and thus cause constipation.[42b] But the augmented activity of these parts (contraction of the bladder and rectum) in very intense periods of emotional stress, when the *thoracico-lumbar* division is strongly innervated, presents a problem the solution of which I do not yet perceive. Possibly in such conditions the orderliness of the central arrangements is upset, just as it is after

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[42] William James: *Loc. cit.*, I, p. 22.

[42a] The pathological cases in which rage or other violent excitement is reported as preceding or following the act are difficult to reconcile with the view here propounded. On careful examination, however, these cases may be found not to contravene the conditions of physiological antagonism in the opposed parts of the autonomic that are excited.

[42b] A. F. Hertz: *Constipation and Allied Intestinal Disorders,* London, 1909, see p. 81.

tetanus toxin or strychnine poisoning, and opposed innervations no longer discharge reciprocally, but simultaneously, and then the stronger member of the pair prevails. Only on such a basis, at present, can I offer any explanation for the activity and the supremacy of the sacral innervation of the bladder and distal colon when the thoracico-lumbar innervation is aroused as, for example, in great fright.

VII. The Similarity of Visceral Effects in Different Strong Emotions and Suggestions as to its Psychological Significance

A summary in few words of the chief functions typically performed or supported by each division of the autonomic would designate the cranial division as the upbuilder and restorer of the organic reserves, the sacral as the servant of racial continuity, and the thoracico-lumbar as the preserver of the individual. Self-preservation is primary and essential; on that depends racial continuity and for that all the resources of the organism are called forth. Analogously the sympathetic innervations, when they meet in organs innervated also by the cranial and sacral divisions, almost with exception predominate over their opponents. And analogously also, the emotional states which are manifested in the thoracico-lumbar division and are characteristically much more intense than those manifested in the other divisions, readily assume ascendency also in consciousness.

These dominant emotions are fear and rage, and they are not unlike. As James has indicated, "Fear is a reaction aroused by the same objects that arouse ferocity. . . . We both fear, and wish to kill anything that may kill us; and the question which of the two impulses we shall follow is usually decided by some one of those *collateral circumstances* of the particular case, to be moved by which is the mark of superior mental natures."[43] The cornering of an animal when in the headlong flight of fear may suddenly turn the fear to fury and the flight to a fighting in which all the strength of desperation is displayed.

Furthermore these dominant emotions are states into which many other commonly milder affective states may be suddenly transformed. As McDougall has pointed out, all instinctive impulses when met with opposition or obstruction give place to, or are complicated by, the pugnacious or combative impulse

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[43] William James: *Loc. cit.*, II, see p. 415.

directed against the source of the obstruction.[44] A dog will bristle at any attempt to take away his food, males will fight furiously when provoked by interference with the satisfaction of the sexual impulse, a man will forget the conventions and turn hot for combat when there is imputation against his honor, and a mother all gentle with maternal devotion is stung to quick resentment and will make a fierce display of her combative resources, if anyone intentionally injures her child. In these instances of thwarted or disturbed instinctive acts the emotional accompaniments—such as the satisfactions of food and of sexual affection, the feeling of self-pride, and the tender love of a parent—are whirled suddenly into anger. And anger in one is likely to provoke anger or fear in the other who for the moment is the object of the strong feeling of antagonism. Anger is the emotion pre-eminently serviceable for the display of power, and fear is often its counterpart. Darwin testifies to having heard " as a proof of the exciting nature of anger, that a man when excessively jaded will sometimes invent imaginary offences and put himself into a passion, unconsciously for the sake of reinvigorating himself "; and Darwin continues, " since hearing this remark, I have occasionally recognized its full truth."

The visceral changes which accompany fear and rage have been previously described as the result of discharges by way of sympathetic fibres. So far as these two quite different emotions are concerned, present physiological evidence indicates that differences in the bodily accompaniments are not noteworthy.[45] And there is, indeed, obvious reason why the visceral changes in fear and rage should not be *different,* but rather, why they should be *alike.* As already pointed out, these emotions accompany organic preparations for action, and just because the conditions which evoke them are likely to result in flight or conflict (either one requiring, perhaps, the utmost struggle) the bodily needs in either response are precisely the same.

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[44] Wm. McDougall: *Loc. cit.,* see p. 72.

[45] Obvious vascular differences, as pallor or flushing of the face, are of little significance. With increase of blood pressure from vasoconstriction, pallor might result from action of the constrictors in the face, or flushing might result because constrictors elsewhere, as, for example, in the abdomen, raised the pressure so high that facial constrictors are overcome. Such, apparently, is the effect of adrenalin, already described (see p. 269). Or the flushing might occur from local vasodilation. That very different emotional states may have the same vascular accompaniments was noted by Darwin (*Loc. cit.*) who mentioned the pallor of rage (p. 74) and also of terror (p. 77).

In discussing the functioning of the thoracico-lumbar division I pointed out that it was roused to activity not only in fear and rage, but also in pain. The machinery of this division likewise is operated wholly or partially in emotions which are usually mild—such as joy and sorrow and disgust—*when they become sufficiently intense.* Thus, for instance, the normal course of digestion may be stopped or quite reversed in a variety of these emotional states.

Darwin reports the case of a young man who on hearing that a fortune had just been left him, became pale, then exhilarated, and after various expressions of joyous feeling vomited the half-digested contents of his stomach.[46] Müller has described the case of a young woman whose lover had broken the engagement of marriage. She wept in bitter sorrow for several days, and during that time vomited whatever food she took.[47] And Burton, in his *Anatomy of Melancholy,* gives the following instance of the effect of disgust:[48] "A gentlewoman of the same city saw a fat hog cut up, when the entrails were opened, and a noisome savour offended her nose, she much disliked, and would not longer abide; a physician in presence told her, as that hog, so was she, full of filthy excrements, and aggravated the matter by some other loathsome instances, insomuch this nice gentlewoman apprehended it so deeply that she fell forthwith a vomiting, was so mightily distempered in mind and body, that with all his art and persuasion, for some months after, he could not restore her to herself again, she could not forget or remove the object out of her sight."

In these three cases, of intense joy, intense sorrow and intense disgust, the influence of the cranial division of the autonomic has been overcome, digestion has ceased, and the stagnant gastric contents by reflexes in striated muscles have been violently discharged. The extent to which under such circumstances other effects of thoracico-lumbar impulses may be manifested, has not, so far as I know, been ascertained.

From the evidence just given it appears that any high degree of excitement in the central nervous system, whether felt as anger, terror, pain, anxiety, joy, grief or deep disgust, is likely to break over the threshold of the sympathetic division

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[46] Chas. Darwin: *Loc. cit.,* see p. 76.

[47] Müller: Klinische Beiträge zur Physiologie des sympathetischen Nervensystems. *Deutsches Archiv für klinische Medicin,* LXXXIX, 1907, 432-456, see p. 434.

[48] Robert Burton: *The Anatomy of Melancholy* (first published in 1621), London, 1886, P + 1, p. 443.

and disturb the quiet of all the organs which that division innervates. It may be that there is advantage in the readiness with which these widely different emotional conditions can express themselves in this one division, for, as has been shown (see p. 264), occasions may arise when these milder emotions are suddenly transmuted into the naturally intense types (as fright and fury) which normally activate this division; and if the less intense can also influence it, the physiological aspect of the transmutation is already partially accomplished.

If various strong emotions can thus be expressed in the diffused activities of a single division of the autonomic—the division which accelerates the heart, inhibits the movements of the stomach and intestines, contracts the blood vessels, erects the hairs, liberates sugar, and discharges adrenalin—it would appear that the bodily conditions which have been assumed, by some psychologists, to distinguish emotions from one another must be sought for elsewhere than in the viscera. We do not "feel sorry because we cry," as James contended, but we cry because, when we are sorry or overjoyed or violently angry or full of tender affection—when any one of these diverse emotional states is present—there are nervous discharges by sympathetic channels to various viscera, including the lachrymal glands. And in terror and rage and intense elation, for example, the responses in the viscera seem too uniform to offer a satisfactory means of distinguishing states which, in man at least, are subjectively very different. For this reason I am inclined to urge that the visceral changes merely contribute to an emotional complex more or less indefinite, but still pertinent, feelings of disturbance, in organs of which we are not usually conscious.

This view that emotions are not of visceral origin is in accord with the experimental results of Sherrington,[49] who has demonstrated that emotional responses occur in dogs in which practically all the main viscera and the great bulk of skeletal muscle have been removed from subjection to and from influence upon the brain, by severance of the vagus nerves and the spinal cord. In these animals no alteration whatever was noticed in the occurrence, under appropriate circumstances, of expressions of voice and features, indicating anger, delight or fear. The argument that these expressions may have been previously established by afferent impulses from excited viscera was met by noting that a puppy only nine

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[49] Charles S. Sherrington: Experiments on the Value of Vascular and Visceral Factors for the Genesis of Emotion. *Proceedings of the Royal Society,* LXVI, 1900, 390-403, see p. 397.

weeks old also continued to exhibit the signs of affective states after the brain was disconnected from all the body except head and shoulders. Evidence from uniformity of visceral response and evidence from exclusion of the viscera are harmonious, therefore, in pointing towards central rather than peripheral changes as the source of differences in emotional states.

If these differences are due to central changes, why is it not always possible by voluntary innervations to produce emotions? We can laugh and cry and tremble. But forced laughter does not bring happiness nor forced sobbing sorrow, and the trembling from cold rouses neither anger nor fear. The muscle positions and tensions are there, but the experiencing of such bodily changes does not seem even approximately to rouse an emotion in us. The *voluntary* assumption of an attitude seems to leave out the " feeling." It is probable, however, that no attitude which we can assume has all the elements in it which appear in the complete response to a stirring situation. But is not this because the natural response is a pattern reaction, like inborn reflexes of low order, such as sneezing, in which impulses flash through peculiarly co-operating neurone groups of the central system, suddenly, unexpectedly, and in a manner not exactly reproducible by volition, and thus they throw the skeletal muscles into peculiar attitudes and, if sufficiently intense, rush out in diffuse discharges that cause tremors and vascular perturbations? The typical facial and bodily expressions, automatically assumed in different emotions and so well known as to constitute the common language between man and beast, indicate the discharge of peculiar groupings of neurones in the several affective states. That these responses occur instantly and spontaneously when the appropriate " situation," actual or vividly imagined, is present, shows that they are ingrained in the nervous organization. At least one such pattern, that of anger, persists after removal of the hemispheres,—the decorticated dog, by growling and biting when handled, has the appearance of being enraged;[50] the decerebrate cat when vigorously stimulated retracts its lips and tongue, stares with dilated pupils, snarls, and snaps its jaws.[51] On the other hand, stroking the hair, whistling, gently calling, or yelling

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[50] Fr. Goltz: Der Hund ohne Grosshirn. *Archiv für die gesammte Physiologie,* LI, 1892, 570-614, see p. 577.

[51] R. S. Woodworth and C. S. Sherrington: A Pseudaffective Reflex and its Spinal Path. *Journal of Physiology,* XXXI, 1904, 234-243, see p. 234.

to produce fright have not the slightest effect in evoking from the decorticated dog, signs of joy, affection or fear, nor does the animal manifest any sexual feeling. The absence of bodily indications of these emotions is quite as significant as the presence of the signs of anger. For, since expressions of anger can persist without the cortex, there is little reason why the complexes of other emotional expressions, if their " machinery " exists below the cortex, should not also be elicitable. That they are not elicitable suggests that they require a more elaborately organized grouping of neurones than does anger—possibly what the cortex, or the cortex in combination with basal ganglia, would provide.

The contrast between the brevity of the " pseudoaffective reactions " in the decerebrate cat, though the viscera are still connected with the central nervous system, and the normal duration of emotional expression in the dog with body separated from the head region, has been used by Sherrington to weigh the importance of the visceral and cerebral factors. And for reasons given above, as well as for the reasons he has offered, I agree with Sherrington's conclusion " that the reverberation from the trunk, limbs and viscera counts for relatively little, even in the primitive emotions of the dog, as compared with the cerebral reverberation to which is adjunct the psychical component of emotional reaction."[52]

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[52] Charles S. Sherrington: *The Integrative Action of the Nervous System,* New York, 1906, pp. xvi + 411, see p. 268.